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DIGESTIBILITY OF COD-LIVER, JAVA-ALMOND, TEA-SEED, AND WATERMELON-SEED OILS, DEER FAT, AND SOME BLENDED HYDROGENATED FATS.

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PURPOSE OF INVESTIGATIONS.

An abundant supply of fat is of major importance in the consideration of nutrition, whether of the individual or the nation. Not only are fats wholesome, palatable, and most useful in cooking, but many also carry fat-soluble vitamin A.

Our older ideas regarding the indispensable rôle of fat in the diet must be somewhat modified if we accept the results of certain recent studies. Osborne and Mendel[1] conclude from experiments on rats that "if true fats are essential for nutrition during growth, the minimum necessary must be exceedingly small" and Drummond,[2] on the basis of similar studies, states that unless minute amounts of fat play as important a rôle in metabolism as do minute quantities of vitamins, it is reasonable to suggest that pure fats are dispensable constituents of the diet. Such findings, however, do not greatly lessen the importance of fats as a foodstuff. During the recent war, in the countries where the fat supply was far below normal, great discomfort and a serious lowering of health and of resistance to

[1] Jour. Biol. Chem., 45 (1920), No. 1, pp. 145–152.
[2] Jour. Physiol., 54 (1920), No. 4, p. XXX.

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disease were common and physiologists generally believe that this was due, to some extent at least, to a lack of vitamin A. It should also be remembered that fats and oils represent the most concentrated source of body fuel, a fact that has an important bearing on the food transportation problem and on the cost of food to the consumer. An adequate national food policy therefore requires that an abundant fat supply be maintained during peace times as well as during war, and there is justification for the efforts made to find new sources of food fats and to make better use of those we now have.

For such reasons the Department of Agriculture has outlined a broad program for the study of edible fats, which includes investigation of the source of supply, methods of production and rectification, the relation of feed to fat production in farm animals, including the cost at which fat is produced at different ages, and the relation of this to the production of meat and dairy products. It also includes studies of the economical use of fat in cookery and its relation to the quality of the cooked product and of the thoroughness of digestion of fats and oils and the tolerance of the body to different kinds. These latter aspects of the problem have been for some years under investigation in the Office of Home Economics of the States Relations Service, cooperation with other bureaus being secured whenever this has seemed desirable.

The digestibility of 60 or more different fats and oils, some of animal and some of vegetable origin, has been tested in the Office of Home Economics. In a few cases, fish oil and avocado fat for instance, the fat was not extracted but was eaten as it occurs in these foods as ordinarily served. In most cases, however, the fat was rendered or otherwise freed from the tissue in which it occurs, and if necessary, further purified. These studies have been reported from time to time in publications of this department and in professional journals.[3] This bulletin reports two groups of studies, one with a variety of fats and oils regarding which information was needed for special reasons, and one with blended hydrogenated fats such as are now in common use.

EXPERIMENTAL METHOD.

The method followed in these experiments was the same as that developed in the previous digestion experiments of this office. No method has yet been devised by which the proportion of nutrients actually digested from any one food material in a mixed diet can be directly measured, and all the methods now in use admit of at least

[3] U. S. Dept. Agr. Buls. 310 (1915), 505 (1917), 507 (1917), 630 (1918), 687 (1918), 613 (1919), 781 (1919); Jour. Biol. Chem., 41 (920), No. 2, pp. 227–235; Amer. Jour. Physiol., 54 (1921), No. 3, pp 479–488

slight chances of error through the assumptions made regarding such factors as metabolic products and the digestibility of the nutrients in the basal diet. The procedure here adopted is believed to give as nearly correct results as any with which this office is familiar, and since it has been consistently followed in all the experiments in this laboratory, the results can be confidently said to show the relative digestibility of the various food materials thus studied. In comparing the results of studies conducted by one method with those by another, due allowance should be made for differences in procedure and calculation, and such allowance will frequently be found to lessen apparent conflicts or discrepancies in the findings which different investigators have obtained from experiments with similar materials.

The subjects in the present experiments were young men apparently in normal health, most of them students in a local university. They were familiar with this type of work, having served as subjects in previous experiments, and were entirely trustworthy. Each experiment was carried on for three days and included nine meals. The methods for separation of the feces, analyses, etc., were those usually followed.

In each experiment the special fat to be studied was incorporated in a cornstarch blanc-mange or pudding. This was eaten along with a basal ration which consisted of commercial wheat biscuit, oranges, and sugar and which supplied a very small amount of fat in comparison with that in the blanc-mange. Clear tea or coffee was included when desired.

The reports of the individual experiments are here presented in condensed form, but full data are on file in the Office of Home Economics.

EXPERIMENTS.

COD-LIVER OIL.

Though long and favorably known in medicine, especially in the treatment of tuberculosis and other wasting diseases, cod-liver oil has had no general use for food purposes. It has, however, entered into the diet to some extent, both the cod livers and the oil finding some use as food. Dr. Vivia Appleton, who has studied diet in Labrador, has stated in personal communications that cod livers are there considered a delicacy and she believes them to be a valuable source of vitamin A. Fishermen from points north of Boston are said to take the crude oil from cod livers and eat it spread on bread. The shortage of fat and particularly milk fat, ordinarily the most important source of vitamin A in child feeding, led Chick and Dalyell[4] to use

[4] Brit. Med. Jour. No. 3109 (1920), pp. 151–154.

cod-liver oil extensively as a food fat in the relief work with children in Vienna after the war. The success of this makes it clear that cod-liver oil can be relied on for such a purpose whenever circumstances make this desirable.

Many experimental studies of cod-liver oil have been reported in medical literature. Some of the most interesting are those dealing with its iodin content, which Andrès, quoted by Lewkowitsch, reports as 0.02 for pale oil and 0.03 per cent[5] for yellow oil, and to which its therapeutic value has been attributed by some.

Osborne and Mendel[6] first noted the remarkable potency of cod-liver oil in vitamin A. More recently Zilva and Miura have shown by new quantitative methods that crude cod-liver oil is in some cases two hundred and fifty times as potent as butter fat and refined cod-liver oil many times superior to butter in this respect.[7] This has naturally aroused much interest in the relation between its vitamin content and its therapeutic value. Such investigations, together with its successful use in the treatment of malnutrition in Vienna, can hardly fail to bring about a more general use of cod-liver oil as food fat.

It is interesting to note that cod-liver oil has been studied in animal feeding, specifically its effect on milk production when used as a supplement to other fat in the ration of dairy cows. Hart, Steenbock, and Hoppert report[8] that the daily addition of from 5 to 10 cubic centimeters of cod-liver oil to the diet of dry and milking goats consistently changed negative calcium balances to positive, showing that some factor affecting calcium assimilation is present in cod-liver oil.

The digestibility of cod-liver oil by man has been studied by Wells,[9] who fed 100 grams per day to human subjects and found that it was well assimilated. No significant difference was noted between the emulsified and the unemulsified oil, the coefficients of digestibility being respectively 96 and 97 per cent. Judging by the results obtained, the cod-liver oil slightly increased the thoroughness of digestion of the other fats present in the experimental ration.

In the experiments made in this laboratory no difficulty was experienced in feeding the cod-liver oil, the flavor being well masked by the caramel and vanilla extract used in the cornstarch pudding which served as a vehicle for the fat. The results of four experiments are summarized in Table 1.

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[5] Chemical Technology and Analysis of Oil, Fats, and Waxes. 1909, 4 ed., vol. 2, p. 361.

[6] Jour. Biol. Chem., 17 (1914), No. 3, pp. 401–408.

[7] Lancet [London], 200 (1921), No. 5085, p. 323.

[8] Jour. Biol. Chem., 48 (1921), pp. 33–50.

[9] Brit. Med. Jour. No. 2181 (1902), pp. 1222–1224.

TABLE 1.—*Summary of digestion experiments with cod-liver oil in a simple mixed diet.*

Experiment No.	Subject.	Digestibility of entire ration.				Digestibility of cod-liver oil alone.
		Protein.	Fat.	Carbohydrate.	Ash.	
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1143	C. J. G.	64.5	91.3	96.4	62.0	97.2
1144	H. L. G.	65.6	96.5	96.6	70.4	100.0
1145	E. L. M.	12.8	88.9	95.9	32.5	95.2
1146	J. F. S.	59.2	93.8	96.6	47.5	98.4
Average		50.5	92.6	96.4	53.1	97.7

The food eaten per man per day provided on an average 16 grams of protein, 47 grams of fat, and 310 grams of carbohydrate, and its fuel value averaged 1,740 calories. The maximum amount of cod-liver oil consumed by any subject was 53 grams per day. The coefficient of digestibility was high in every case, and the average figure, 97.7 per cent, indicates a very complete utilization. Except that all the subjects were somewhat constipated, no physiological disturbance was noted.

In thoroughness of digestion, cod-liver oil agrees closely with the majority of fats and oils that have a melting point at or below body temperature.

JAVA-ALMOND OIL.

The digestibility of this oil is of interest not only because the nut is valued highly in Java, but also because the finely ground kernels mixed with water to a kind of emulsion and added to milk find there a special use in infant feeding with, it is believed, good results.

The Java almonds (*Canarium commune*) needed for this experiment were obtained from Java by the Office of Foreign Seed and Plant Introduction, Bureau of Plant Industry. The nut resembles somewhat a small-sized pecan in shape, and the kernels are much like a small almond in appearance and have a very agreeable flavor.

In the present work a small-sized laboratory oil press was used to express the oil, which was of clear yellow color and bland in flavor.

The supply available was sufficient for only two tests. The results are summarized in Table 2.

TABLE 2.—*Summary of digestion experiments with Java-almond oil in a simple mixed diet.*

Experiment No.	Subject.	Digestibility of entire ration.				Digestibility of Java-almond oil alone.
		Protein.	Fat.	Carbohydrate.	Ash.	
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1154	H. L. G.	52.2	95.5	96.2	66.3	99.4
1155	E. L. M.	30.5	89.0	96.5	36.6	94.5
Average		41.4	92.2	96.4	51.4	97.0

The food eaten per man per day provided on an average 15 grams of protein, 61 grams of fat, and 311 grams of carbohydrate and its fuel value averaged 1,860 calories. The average coefficient of digestibility of the Java-almond oil, which made up over 98 per cent of the total fat of the diet, was 97 per cent. So far as may be judged by the continued good condition of the subjects, the palatability of the oil, and its high digestibility, there is good reason to conclude that it compares favorably with other nut oils used in this laboratory.

TEA-SEED OIL.

The best grades of tea-seed oil are used to some extent for food purposes in China and have been found as an adulterant of cabbage oil. The Chinese use poorer grades for burning and for soap making. That used in the tests here reported was a commercial product of a pale yellow color and bland flavor.

The fitness of this by-product oil for food has been questioned on the ground that, as saponin has been found in it, it may be harmful. Hooper[10] reports 9 per cent saponin in tea seed and states that some is always dissolved by the oil. Weil[11] states that oil made by extraction contains no saponin. The oil used in the present experiments was examined for saponin in the Pharmacological Laboratory, Bureau of Chemistry, with negative results.

The experiment was begun with three subjects, who ate some 40 to 50 grams of the oil per man per day. Owing to the accidental loss of some of the feces in the case of two subjects, complete data are available from only one person. The available results are summarized in Table 3.

TABLE 3.—*Data of digestion experiments with tea-seed oil in a simple mixed diet.*

Experiment No.	Subject.	Digestibility of entire ration.				Digestibility of tea-seed oil alone.
		Protein.	Fat.	Carbohydrate.	Ash.	
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1004	J. F. C.	47.2	88.2	98.4	42.1	91.2

The daily food of the subject for whom the experimental data are complete, provided on an average 9 grams of protein, 50 grams of fat, and 204 grams of carbohydrate, and its fuel value averaged 1,300 calories. The average amount of tea-seed oil eaten daily was 49 grams. The subject remained in his usual good health and suffered no noticeable physiological disturbances. This was equally

[10] Pharm. Jour. and Trans. [London], 3. ser., 25 (1895), No. 1282, p. 605.
[11] Arch. Pharm., 239 (1901), No. 5, pp. 365.

true for the two other subjects, both of whom ate the experimental diet for three days. The coefficient of digestibility, 91.2 per cent, obtained in the one complete test is somewhat lower than is usual with oils liquid at body temperature, but the data are too limited to be taken as conclusive. All that can fairly be said on the basis of the work here reported is that tea-seed oil appeared to be well tolerated and over 90 per cent digested.

WATERMELON-SEED OIL.

Watermelon-seed oil is at present made only for experimental purposes, but its possible economic and commercial importance is suggested by the fact that another cucurbit fat previously studied, pumpkin-seed oil, is well known as a food product. It was therefore included in the present series of tests.

Watermelon-seed oil is easily expressed from the seed which, according to Lewkowitsch [12] will yield 40.8 per cent. It is light brown in color and pleasing in flavor. That used in the experiments here reported was obtained through the courtesy of F. Rabak, of the Bureau of Plant Industry. The quantity available was limited and so the amount supplied per day to the subjects was less than usual in such experiments.

Tests were made with three subjects. The results are summarized in Table 4.

TABLE 4.—*Summary of digestion experiments with watermelon-seed oil in a simple mixed diet.*

Experiment No.	Subject.	Digestibility of entire ration.				Digestibility of watermelon-seed oil alone.
		Protein.	Fat.	Carbohydrate.	Ash.	
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
999	J. F. C.	66.9	89.4	98.6	53.7	92.5
1001	G. S. M.	41.6	88.5	97.0	29.7	93.9
1002	W. O'C.	62.2	94.2	98.0	27.8	97.9
Average		56.9	90.7	97.9	37.1	94.8

The total food consumed per man per day supplied on an average 9 grams of protein, 32 grams of fat of which nearly 30 grams were watermelon-seed oil, and 215 grams of carbohydrate, and its fuel value averaged 1,190 calories. No special physiological effects were noted and the coefficient of digestibility, 94.8 per cent, was relatively high. In general it can be said that watermelon-seed oil resembles the two other cucurbit-seed oils previously studied, cantaloup and pumpkin-seed oils, both of which had a coefficient of diges-

[12] Chemical Technology and Analysis of Oils, Fats, and Waxes. 1909, 4. ed., vol. 2, p. 126.

tibility of 98.2 per cent.[13] Like these oils it was well tolerated and so far as can be judged would be useful for food purposes if available commercially.

DEER FAT.

While the fat of the various species of deer is not a commercial product in the United States, in some localities it is a constituent of the human dietary, especially during the open season. In this connection it is interesting to recall that in Alaska the carcass as well as the milk of the reindeer is used for food and reindeer fat forms no inconsiderable part of the diet. The importance of caribou fat in the diet of natives and others in the Arctic region is well brought out in accounts of such travelers and explorers as Stefánsson.[14]

For the experiments reported below two shipments of fat from white-tailed Virginia deer were obtained through the courtesy of John B. Burnham, president of the American Game Protective and Propagation Association. The crude deer fat was taken from a number of animals shot in New England and New York during late fall and early winter. No information was available concerning the part of the body from which the fat was taken, but in general appearance the crude fat resembled somewhat the "leaf" or kidney fat of mutton. The various lots received were rendered together and the product is believed to be typical of deer fat. Its melting point was found to be 51.4° C. This is not unlike the figures quoted by Lewkowitsch,[15] which show that the melting points of fat from different species of deer vary between 49° C. and 54° C.

Only three experiments were made as the available supply of deer fat was limited. The results are summarized in Table 5.

TABLE 5.—*Summary of digestion experiments with deer fat in a simple mixed diet.*

Experiment No.	Subject.	Digestibility of entire ration.				Digestibility of deer fat alone.
		Protein.	Fat.	Carbohydrate.	Ash.	
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
750	P. K.	59.5	71.5	95.5	47.0	78.0
752	J. C. M.	65.3	73.9	95.8	45.4	81.2
753	A. A. R.	31.9	75.4	95.6	41.0	85.8
Average		52.2	73.6	96.0	44.5	81.7

The food eaten per man per day provided on an average 25 grams of protein, 46 grams of fat, and 311 grams of carbohydrate, and its fuel value averaged 1,760 calories. The diet as a whole was well

[13] U. S. Dept. Agr. Bul. 781 (1919).

[14] My Life with the Eskimo. 1913.

[15] Chemical Technology and Analysis of Oils, Fats, and Waxes. 1909, 4. ed., vol. 2, pp. 723, 724.

assimilated, no physiological disturbance was noted, and the deer fat, though its melting point is rather high as compared with common food fats, did not lower the digestibility of the other ingredients of the diet.

The average figure reported for digestibility of deer fat, 81.7 per cent, is considerably lower than that found in most of the experiments made in this laboratory with fats. The only exceptions were hydrogenated peanut oil which had a melting point of 52.4° C. and showed practically the same coefficient of digestibility,[16] 79 per cent, and oleo stearin which was 80.1 per cent digested.[17]

Though the amount of deer fat eaten per man per day is small compared with other fats previously studied in this laboratory, it constituted the major portion of the total fat eaten in all three tests and there seems no reason to doubt the accuracy of the results.

The average results of the experiments with cod-liver, Java-almond, tea-seed, and watermelon-seed oils and deer fats are summarizd in Table 6.

TABLE 6.—*Summary of results of digestion experiments with certain miscellaneous oils and fat in a mixed diet.*

Material tested.	Digestibility of entire ration.				Digestibility of oil or fat alone.
	Protein.	Fat.	Carbohydrate.	Ash.	
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Cod-liver oil	50.5	92.6	96.4	53.1	97.7
Java-almond oil	41.4	92.2	96.4	51.4	97.0
Tea-seed oil	47.2	88.2	98.4	42.1	91.2
Watermelon-seed oil	56.9	90.7	97.9	37.1	94.8
Deer fat	52.2	73.6	96.0	44.5	81.7

BLENDED HYDROGENATED FATS.

During the last 10 or 15 years the hydrogenation process has come prominently into use for the preparation of solid fats from liquid oils. This procedure, although limited in general use to those oils which have a fairly large amount of unsaturated fatty acids, finds application in the hardening of a number of vegetable and animal oils that are produced in quantity.

There are two general methods for the preparation of hydrogenated fats. In one, all the oil is subjected to the hydrogenation process until a fat of the desired melting point is obtained. In the other, part of the oil is hydrogenated until a fat with a very high melting point is obtained, which is then mixed with a sufficient amount of the untreated oil to give a fat of the desired melting point. In the discus-

[16] Amer. Jour. Physiol., 54 (1921), No. 3, pp. 479–488.
[17] U. S. Dept. Agr. Bul. 613 (1919).

sion which follows such fats are designated "blended fats" in contrast to the "hydrogenated oils" made by hydrogenating the entire quantity of oil.

It has been claimed that this blended fat is inferior in keeping qualities to that produced by hydrogenation alone.[18] The blending method is, however, generally given preference because of the larger production possible with a given equipment. Moreover, the blended fat may supply vitamins, if any were present in the oil that is blended with the hardened fat.

A previous paper from this laboratory reported a series of 44 experiments on corn, cottonseed, and peanut oils hydrogenated to different degrees of hardness.[19] It was found that with the exception of hydrogenated peanut oil melting at 52.4° C., which was 79 per cent digested, and corn oil melting at 50° C., which was 88.5 per cent digested, the hydrogenated oils studied had coefficients of digestibility of 92 per cent or higher. No one of them caused any observed digestive disturbance nor was a decrease in the digestibility of the experimental diet as a whole noted in any case. In general, the results showed that as the melting point of the hydrogenated oil increased the digestibility decreased, the decrease being much more marked with those melting at over 46° C.

To determine whether or not blended fats have the same digestibility as hydrogenated oils made from the same kinds of oils and having approximately the same melting point, such blended fats were used in the experiments here reported. They were made for the purpose from the same lots of corn, cottonseed, and peanut oils used in the earlier experiments with hydrogenated oils.[20]

The hard fats used in the preparation of the majority of the blended fats were prepared in the laboratory of Carleton Ellis by one of the authors (H. J. D.) of this bulletin assisted by J. R. Kuhn. The oils were completely saturated with hydrogen at 180° C. and had a melting point, in every case, of approximately 60° C. In the case of the two blended cottonseed fats, with melting points of 41.3° C. and 50° C., cotton stearin obtained from the Bureau of Animal Industry was mixed with a good grade of commercial edible cottonseed oil obtained from the Bureau of Chemistry. The melting points, iodin numbers, and proportions of hardened and untreated oil in the fats used are shown in Table 10, page 13.

These blended fats were white, solid or practically so at room temperature, and without any characteristic odor or taste. When melted, their color was yellow, resembling that of tallow. If allowed

[18] Rogers, A. Manual of Industrial Chemistry. 1915, 2. ed., p. 601.

[19] Holmes, A. D., and Deuel, H. J., jr., Amer. Jour. Physiol., 54 (1921), No. 3, pp. 479–488.

[20] Amer. Jour Physiol., 54 (1921), No. 3, pp. 479–488.

to cool slowly, the stearin separated out leaving a liquid layer on top of it. When cooled quickly with continued stirring, a homogenous, white compound was obtained which resembled lard.

Blended corn fats.—Ten digestion experiments were conducted with blended corn fat, four with fat melting at 39° C. and three each with fats melting at 49° C. and 54° C. The results are summarized in Table 7.

TABLE 7.—*Summary of digestion experiments with blended corn fats in a simple mixed diet.*

Experiment No.	Melting point of fat.	Subject.	Digestibility of entire ration.			Digestibility of blended corn fat alone.
			Protein.	Fat.	Carbohydrate.	
	°C.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1113	39	P. C.	56.3	94.4	96.7	97.2
1115	39	H. L. G.	67.1	94.9	97.0	97.4
1116	39	E. L. M.	13.0	90.5	96.8	94.4
1117	39	J. F. S.	54.9	88.5	96.2	91.9
Average			47.8	92.1	96.7	95.2
1128	49	H. L. G.	67.4	91.7	95.6	94.9
1129	49	E. L. M.	59.9	92.4	98.0	94.7
1130	49	J. F. S.	58.4	87.0	96.5	90.2
Average			61.9	90.4	96.7	93.3
1132	54	H. L. G.	65.3	89.7	96.8	93.0
1133	54	E. L. M.	29.1	83.5	96.1	88.5
1134	54	J. F. S.	64.2	90.1	96.8	92.9
Average			52.9	87.8	96.6	91.5

The average amount of blended corn fat eaten per man per day was 102.9 grams for the fat melting at 39°C., 105.4 grams for the fat melting at 49° C., and 92.5 grams for the fat melting at 54° C. The maximum amounts eaten per day were 121.2 grams of fat melting at 39° C. in experiment No. 1117, 126.2 grams of fat melting at 49° C. in experiment No. 1130, and 103.7 grams of fat melting at 54° C. in experiment No. 1134. The digestibility of the blended corn fat was on an average 95.2 per cent for the 39° fat, 93.3 per cent for the 49° fat, and 91.5 per cent for the 54° fat. The subjects experienced no physiological disturbances during the three-day experimental periods.

The blended fat melting at 54° was somewhat better digested than the hydrogenated corn oil melting at 50° used in the earlier experiments, although the blended fat was eaten on an average in twice as large amounts as the hydrogenated fat.

Blended cottonseed fats.—Thirteen experiments are reported with blended cottonseed fat, two each with the fat melting at 41.3° C., 45.8° C., and 48.1° C., three with the fat melting at 50° C., and four with the fat melting at 47.8° C. The results are summarized in Table 8.

TABLE 8.—*Summary of digestion experiments with blended cottonseed fats in a simple mixed diet.*

Experiment No.	Melting point of fat.	Subject.	Digestibility of entire ration.			Digestibility of blended cottonseed fat alone.
			Protein.	Fat.	Carbohydrate.	
	°C.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
479	41.3	H. R. G.	57.7	92.8	94.8	97.8
481	41.3	P. K.	76.8	91.9	96.8	95.4
Average			67.2	92.4	95.8	96.6
1149	45.8	E. L. M.	61.1	90.5	97.5	94.6
1150	45.8	J. F. S.	56.4	93.8	96.7	98.2
Average			58.8	92.2	97.1	96.4
1135	47.8	C. J. G.	66.6	85.4	95.5	90.0
1136	47.8	H. L. G.	58.8	92.0	96.0	96.3
1137	47.8	E. L. M.	49.3	91.2	95.7	94.5
1138	47.8	J. F. S.	75.4	94.0	97.9	96.1
Average			62.5	90.7	96.8	94.2
1152	48.1	E. L. M.	61.8	90.2	97.5	93.7
1153	48.1	J. F. S.	40.0	89.5	95.8	95.0
Average			50.9	89.8	96.6	94.4
421	50	H. R. G.	55.7	76.3	96.7	82.6
423	50	R. L. S.	64.8	85.6	97.5	89.9
424	50	O. E. S.	61.5	84.1	97.5	88.4
Average			60.7	82.0	97.2	87.0

The subjects ate on an average per man per day 62.3 grams of the fat melting at 41.3° C., 52.6 grams of the fat melting at 45.8° C., 76.3 grams of the fat melting at 47.8° C., 49.4 grams of the fat melting at 48.1° C., and 56.9 grams of the fat melting at 50° C. The maximum eaten per day was 63.3 grams of the 41.3° C. fat, 52.8 grams of the 45.8° C. fat, 98.1 grams of the 47.8° C. fat, 53.3 grams of the 48.1° C. fat, and 62.7 grams of the 50° C. fat. The average coefficients of digestibility found were 96.6 per cent for the 41.3° C. fat, 96.4 per cent for the 45.8° C. fat, 94.2 per cent for the 47.8° C. fat, 94.4 per cent for the 48.1° C. fat, and 87 per cent for the 50° C. fat. The subjects remained in normal health except for the experiments with fat melting at 50° C. In the reports of their condition in this case the subjects mentioned a feeling of nausea and headache. Such conditions were not noted in the other experiments with hydrogenated fats of high melting point and may not be directly ascribable to the fat ingested. Similar effects had been noted in earlier experiments in which cocoa fat[21] and cupuassú fat[22] were eaten in large quantities.

Blended peanut fats.—Thirteen experiments were conducted with blended peanut fat, five with fat melting at 43° C. and four each with fats melting at 43.2° C. and 51.1° C. The results are summarized in Table 9.

[21] U. S. Dept. Agr. Bul. 505 (1917).

[22] Jour. Biol. Chem., 41 (1920), No. 2, pp. 227–235. Cupuassú fat is expressed from the seed of the fruit of the cupuassu tree (*Theobroma grandiflora* Schum).

TABLE 9.—*Summary of digestion experiments with blended peanut fats in a simple mixed diet.*

Experiment No.	Melting point of fat.	Subject.	Digestibility of entire ration.			Digestibility of blended peanut fat alone.
			Protein.	Fat.	Carbohydrate.	
	°C.		Per cent.	Per cent.	Per cent.	Per cent.
1088	43	P. C.	63 3	94.2	96 2	98.4
1089	43	W. V. D.	71.0	91.5	98 3	94.5
1090	43	H. L. G.	53.4	91.5	96.1	96.0
1091	43	E. L. M.	61.5	93 0	97.1	96.4
1092	43	J. F. S.	63.4	93.1	96 3	97.6
Average			62 5	92 7	96.8	96.6
1093	43.2	P. C.	78.0	95.7	97.2	98.4
1094	43.2	W. V. D.	76.7	97.0	98 7	99.3
1095	43.2	H. L. G.	66.9	93.4	96.6	96.7
1097	43.2	J. F. S.	52.4	91.3	96.8	95.2
Average			68.5	94.4	97 3	97.4
1098	51.1	P. C.	58.4	91.8	97.5	94.3
1100	51.1	H. L. G.	61.5	89.4	97.1	92 8
1101	51.1	E. L. M.	56.0	87.2	97.3	90.8
1102	51.1	J. F. S.	75 8	90.8	97.7	93.2
Average			62.9	89.8	97.4	92.8

The subjects ate on an average per man per day 73.8 grams of the fat melting at 43° C., 79.7 grams of the fat melting at 43.2° C., and 90.3 grams of the fat melting at 51.1° C. The maximum amount of blended peanut fat eaten per man per day was 78.4 grams of the 43° C. fat, 100.1 grams of the 43.2° C. fat, and 109.6 grams of the 51.1° C. fat.

The average coefficients of digestibility were 96.6 per cent for the 43° C. fat, 97.4 per cent for the 43.2° C. fat, and 92.8 per cent for the 51.1° C. fat. The subjects remained in apparently normal health and suffered no physiological disturbances.

Discussion.—A summary of the results obtained from these experiments with blended fats of different melting points prepared out of corn, cottonseed, and peanut oil is given in Table 10.

TABLE 10.—*Summary of digestion experiments with blended vegetable fats in a simple mixed diet.*

Number of experiments conducted.	Kind of fat.	Melting point of fat.	Iodin number.	Fats in blend.		Digestibility of blended fat alone.
				Hardened fat.	Untreated oil.	
		°C.		Per cent.	Per cent.	Per cent.
4	Corn	39	89.7	9.1	90.9	95.2
3	do	49	84.8	25.0	75.0	93.3
3	do	54	85.8	30.8	69.2	91.5
2	Cottonseed	41.3				96.6
2	do	45.8	84.8	12.5	87.5	96.4
4	do	47.8	82.4	18.8	81.2	94.2
2	do	48.1	80.0	23.5	76 5	94.4
3	do	50.0		22.1	77.9	87.0
5	Peanut	43.0	80.9	6.2	93.8	96.6
4	do	43.2	82.4	9.1	90.9	97.4
4	do	51.1	75.5	33.3	66.7	92.8

The fats studied showed coefficients of digestibility ranging from 91.5 to 97.4 per cent, except in blended cottonseed fat melting at 50° C., which gave a coefficient of digestibility of 57 per cent. It is interesting to note that the blended fat with the highest melting point, namely, corn fat melting at 54° C., was 91.5 per cent digested, while straight hydrogenated peanut fat with a melting point of 52.4° C. was found to be only 79 per cent digested.

A comparison between Table 10 and Table 11, adapted from the report [23] of earlier work with hydrogenated oils of the same origin as those used in blended form, gives an idea of the relative effect of the two methods of preparation upon digestibility.

TABLE 11.—*Summary of digestion experiments with hydrogenated vegetable oils in a simple diet.*

Number of experiments conducted.	Kind of fat.	Melting point of fat.	Iodin number.	Digestibility of entire ration.			Digestibility of hydrogenated vegetable oil alone.
				Protein.	Fat.	Carbohydrate.	
		° C.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
5	Cottonseed	35	89.6	69.2	93.6	96.9	96.8
1	do	38.6	.....	69.5	92.7	97.3	95.5
3	do	46	72.8	71.7	92.7	97.6	94.9
5	Peanut	37	81.3	69.1	95.0	96.9	98.1
3	do	39	.....	74.0	93.3	97.6	95.9
5	do	43	78.8	73.8	93.5	96.8	96.5
4	do	50	58.5	68.6	88.1	97.6	92.0
3	do	52.4	.....	55.9	73.8	97.2	79.0
5	Corn	33	89.0	72.0	91.7	97.4	94.7
5	do	43	74.9	76.3	91.8	97.0	95.4
5	do	50	55.4	69.6	83.2	97.3	88.5

The blended fats seem to be, as a rule, slightly better utilized than the straight hydrogenated oils melting at the same temperature.

While no definite data are available regarding the cause of higher digestibility for blended fats, it is not without interest to suggest, as was done in an earlier paper, that in the process of digestion saponification may take place only on the exterior of the particles of hardened fat (i. e., for those melting at temperatures considerably above that of the human body), which decrease in size as the process of digestion continues. If surface area be thus a factor, then the rate of digestion and possibly the extent of digestion of a hydrogenated fat having a high melting point is governed to some extent by the size of the particles of hydrogenated fat ingested. If this hypothesis be tenable, it follows that particles of blended fat which are honeycombed with veins of a low melting fat would, after they had come to the temperature of the body, present greater surface area than particles of straight hydrogenated oil, which present only an exterior surface to the action of the digestive juices.

[23] Amer. Jour. Physiol., 54 (1921), No. 3, pp. 479–488.

The blended fats were eaten in relatively large quantities and caused no apparent physiological disturbances. While the number of experiments here reported is small, it is believed the data are sufficient to permit the conclusion that the digestibility of these blended fats compares favorably with that of the natural fats of corresponding melting points.

SUMMARY OF RESULTS.

For purposes of general comparison the average results of the preceding experiments on the digestibility of oils and fats are summarized in Table 12.

TABLE 12.—*Average digestibility of oils and fats in a mixed diet.*

Kind of oil or fat.	Melting point.	Digestibility.	Kind of oil or fat.	Melting point.	Digestibility.
	° *C.*	*Per cent.*		° *C.*	*Per cent*
Cod-liver oil		97.7	Blended hydrogenated fats:		
Java-almond oil		97.0	Cottonseed fat	41.3	96.6
Tea-seed oil		91.2	Do	45.8	96.4
Watermelon-seed oil		94.8	Do	47.8	94.2
Deer fat	51.4	81.7	Do	48.1	94.4
Blended hydrogenated fats:			Do	50.0	87.0
Corn fat	39.0	95.2	Peanut fat	43.0	96.6
Do	49.0	93.3	Do	43.2	97.4
Do	54.0	91.5	Do	51.1	92.8

In general the results obtained in these studies agree with those reported in the other investigations made by this office on the digestibility of fats and oils.

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